Quantifying the Impact of Dust on Ice Generation in Supercooled Stratiform Clouds

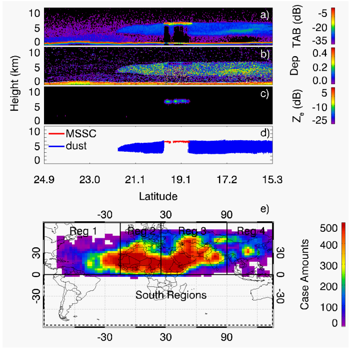
Research Highlight

Heterogeneous ice nucleation is critical for precipitation and to Earth's radiation budget but is still poorly understood because of the largely unknown properties of aerosol particles that serve as ice nuclei (IN). Dust particles have been widely recognized as efficient IN and as one of the major IN sources. Understanding the impact of dust on ice generation plays an important role in disentangling the complicated relationships between aerosols and IN concentrations in clouds.

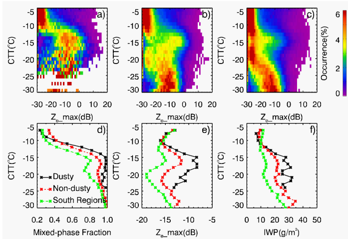
Scientists at the University of Wyoming analyzed four years of collocated CALIPSO and CloudSat measurements to quantify the impact of dust on ice generation in midlevel supercooled stratiform clouds (MSSCs) over the "dust belt." The collocated CALIPSO lidar and CloudSat radar measurements provide a unique data set to globally detect MSSCs and ice generation within them. CALIPSO lidar backscattering and depolarization measurements also offer a reliable way to detect dense dust layers surrounding MSSCs. In this study, dusty MSSCs were found in the region of latitudes between 0N and 45N and longitudes between 75W and 135E.

Due to the weak updrafts and turbulence in MSSCs, ice crystals are primarily formed in the upper part of the supercooled cloud layer, grow large in a water-saturated environment, and fall out of the mixed-phase layer. This simple ice generation and growth pattern offers opportunities to use radar reflectivity (Ze) measurements to quantitatively infer the ice concentration. Under similar meteorological conditions in terms of cloud top temperature (CTT) and liquid water path (LWP), ice crystal growths in MSSCs are expected to be statistically identical. This hypothesis was supported by integrated remote sensing and in situ measurements during the ICE-L campaign.

Analysis from four years of collocated CALIPSO/CloudSat measurements provided robust evidence that statistically supports the assertion that dust particles are efficient IN at temperatures colder than -10°C. We showed that dusty MSSCs are more likely to produce ice particles and contain an up to 20% higher mixed-phase cloud occurrence under similar meteorological conditions. Dusty MSSCs also have a higher IWP of up to 11.5 g/m2 than that of the "South Regions" cases, which could result in a significant change of the cloud radiative forcing of MSSCs. Observed Ze_max differences indicated that dust can enhance ice concentration in MSSCs by a factor of 2 to 6, compared with background aerosol conditions. The ice concentration enhancements were strongly dependent on the CTT and dust particle properties, such as their size and chemical compositions. Because of the high sensitivities of liquid-phase properties in mixed-phase clouds on IN concentration, these results indicate that reliable simulations of dust impacts on ice generation in climate models are critical to capturing aerosol-cloud-radiation-dynamics feedback.



An example of dusty MSSC: (a) CALIOP TAB profiles at 532nm; (b) CALIOP depolarization profiles at 532nm; (c) CloudSat CPR radar reflectivity profiles; (d) Identified dust layers and MSSC; (e) Global distribution of dusty MSSCs in terms of numbers of profiles in 2.5° ×2.5° grid boxes from four years of collocated CALIPSO/ CloudSat measurements.



(a) The occurrence of dusty MSSCs in terms of CTT and Ze_max within the TAB value of 0.31–0.45 (sr-1km-1); (b) for non-dusty MSSCs; (c) for "South Regions" MSSCs; (d) Mean mixed-phase occurrence at given CTT for dusty, non-dusty or "South Regions" MSSCs; (e) Same as (d), but for the mean Ze_max of mixed-phase MSSCs; (f) Same as (d), but for the mean IWP of mixed-phase MSSCs.

Reference(s)

Zhang D, Z Wang, A Heymsfield, J Fan, D Liu, and M Zhao. 2012. "Quantifying the impact of dust on heterogeneous ice generation in midlevel supercooled stratiform clouds." Journal of Geophysical Research – Atmospheres, 39, L18805, doi:10.1029/2012GL052831.

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Cloud-Aerosol-Precipitation Interactions